Sharing technology for a stronger America

Automobiles as Cyber Physical Systems

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4/11/2011

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What is USCAR?

The United States Council for Automotive Research LLC (USCAR) is the umbrella organization for collaborative research among Chrysler LLC, the Ford Motor Company and the General Motors Corporation. Founded in 1992, the goal of USCAR is to further strengthen the technology base of the domestic auto industry through cooperative research and development.

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USCAR Mission

- Create, support and direct U.S. cooperative research and development to advance automotive technologies

- Be responsive to the needs of our environment and society and include the appropriate public and private stakeholders as required

Brief History

- In the beginning the world was mechanical.
  - Carburetors, Distributors and vacuum.
- Once we reached the limit of mechanical solutions, we went to computers with assembly language and integer only processors.
  - Initially spark control, then moved to fuel and egr.
- Again we reached a limit with that level of abstraction and moved to floating point processors and C.
  - Variable cam timing, electronic throttle, transmission control (CVT).

Model Based Design Today

- With the advent of yet more complicated control with increasing pressure on robustness and time to market.
  - Move on to model based design of controls.
    - Graphical programming
    - Data and control flow
    - Automatic code generation
  - Distributed control
    - Stability control
      - brakes and torque control with AWD

What is the next level of abstraction?

- We can design complex controls, however it is still in a virtual mono-processor world.
- How do we reason about performance impacts of system design?
  - Distributed controls
  - Network communications impact
  - End to end scheduling
  - Failure modes

What's CPS got to do with it?

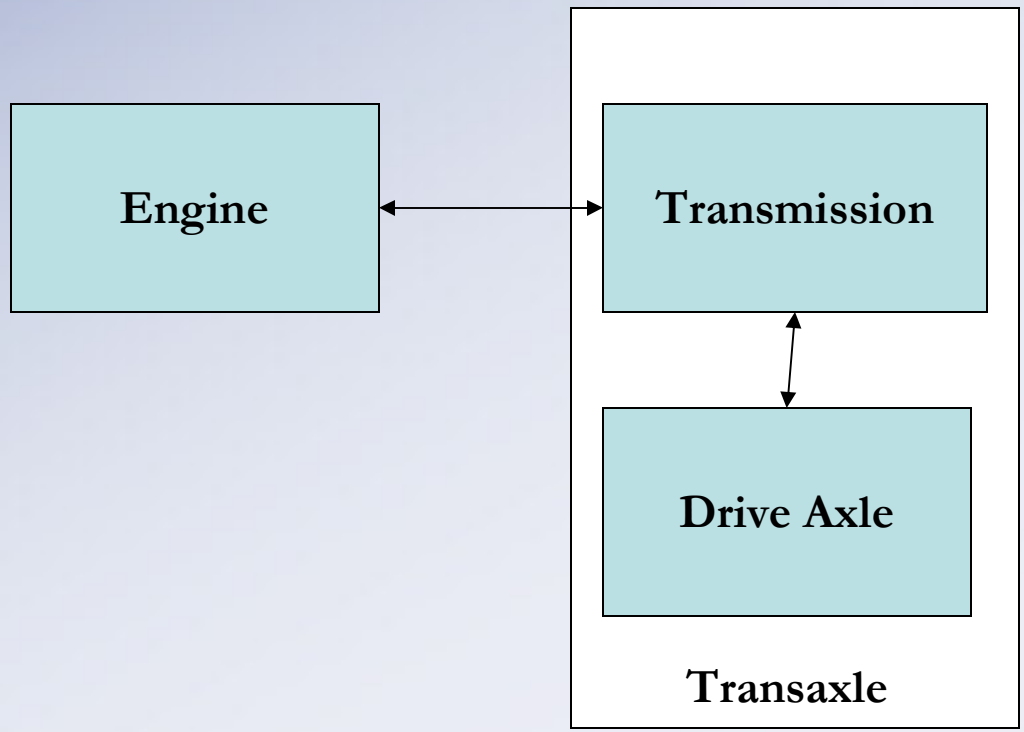
- Marriage of physical component and computer processing.
  - Smart material
  - Intelligent composition of sub-systems
    - It's more than signal compatibility
  - Composition at multiple levels
    - Vehicle platooning
    - Semi/fully autonomous vehicles
    - Vehicle highway coordination
    - Combined end to end multi-modal transportation
    - Context sensitive operating modes
      - High density area carbon tax
      - Powertrain mode operation tied to geography.

Physical Architecture

- The physical components of the vehicle.
  - Engine: Converts air and fuel to power
    - Could be piston, rotary, turbine..
  - Transmission: Multiplies the engine power
    - Uses gears to leverage engine output
  - Drive Axle: Converts the power from the transmission
    - Turns the wheels

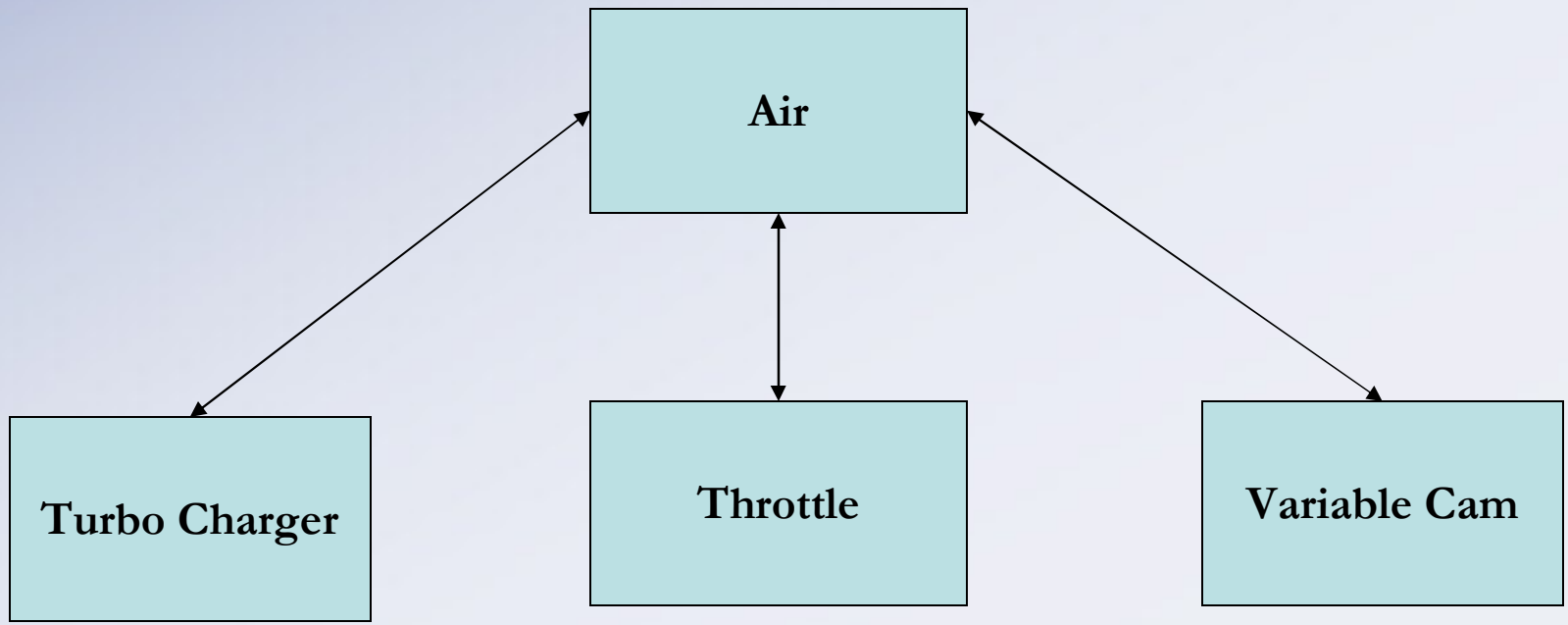
Physical Architecture

Physical Architecture



A transaxle is usually front wheel drive. There are examples of rear wheel drive transaxles, but mainly high end vehicles. With front drive you are now applying torque at the steering wheels and can result in torque steer.

Physical Architecture



Electrical Architecture

- What most automotive people think of when they hear the word architecture
  - Used to be tied directly to the wiring harness
  - Now more tied to the network architecture

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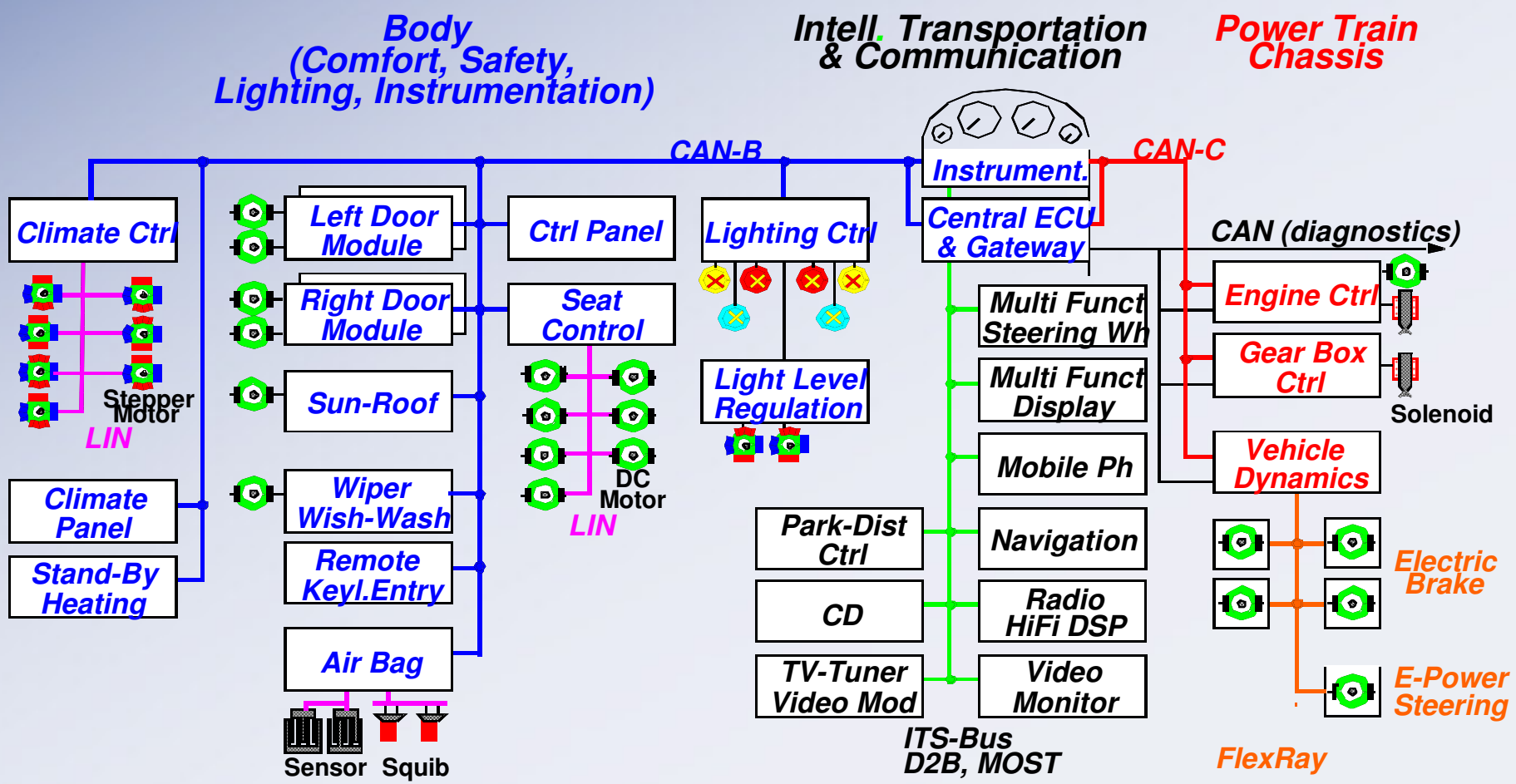
Electrical Architecture



Courtesy Freescale

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Functional Control Architecture

- An abstract view of the relationships between components of the control system.
  - Much like a Simulink model

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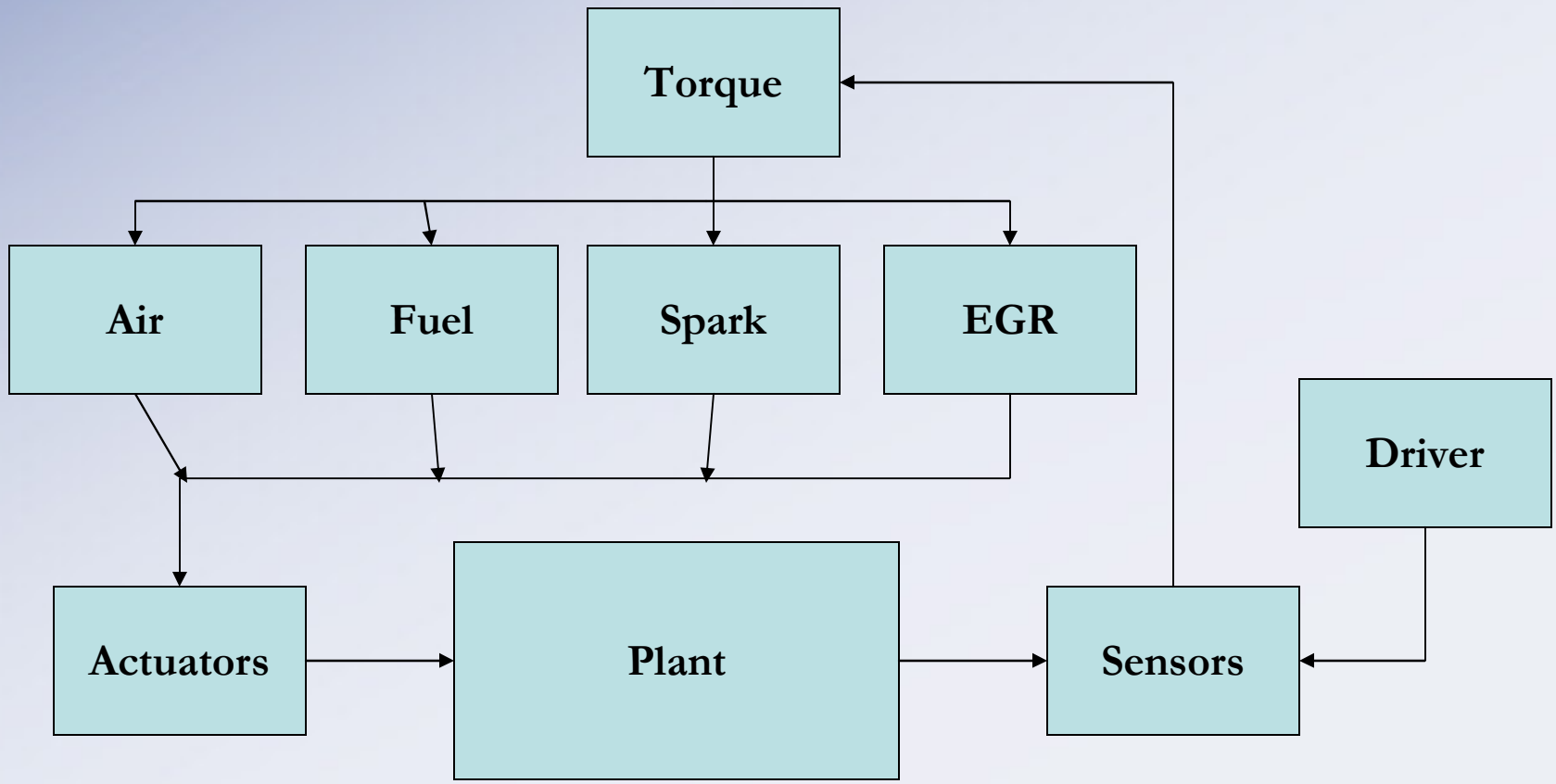
Functional Control Architecture



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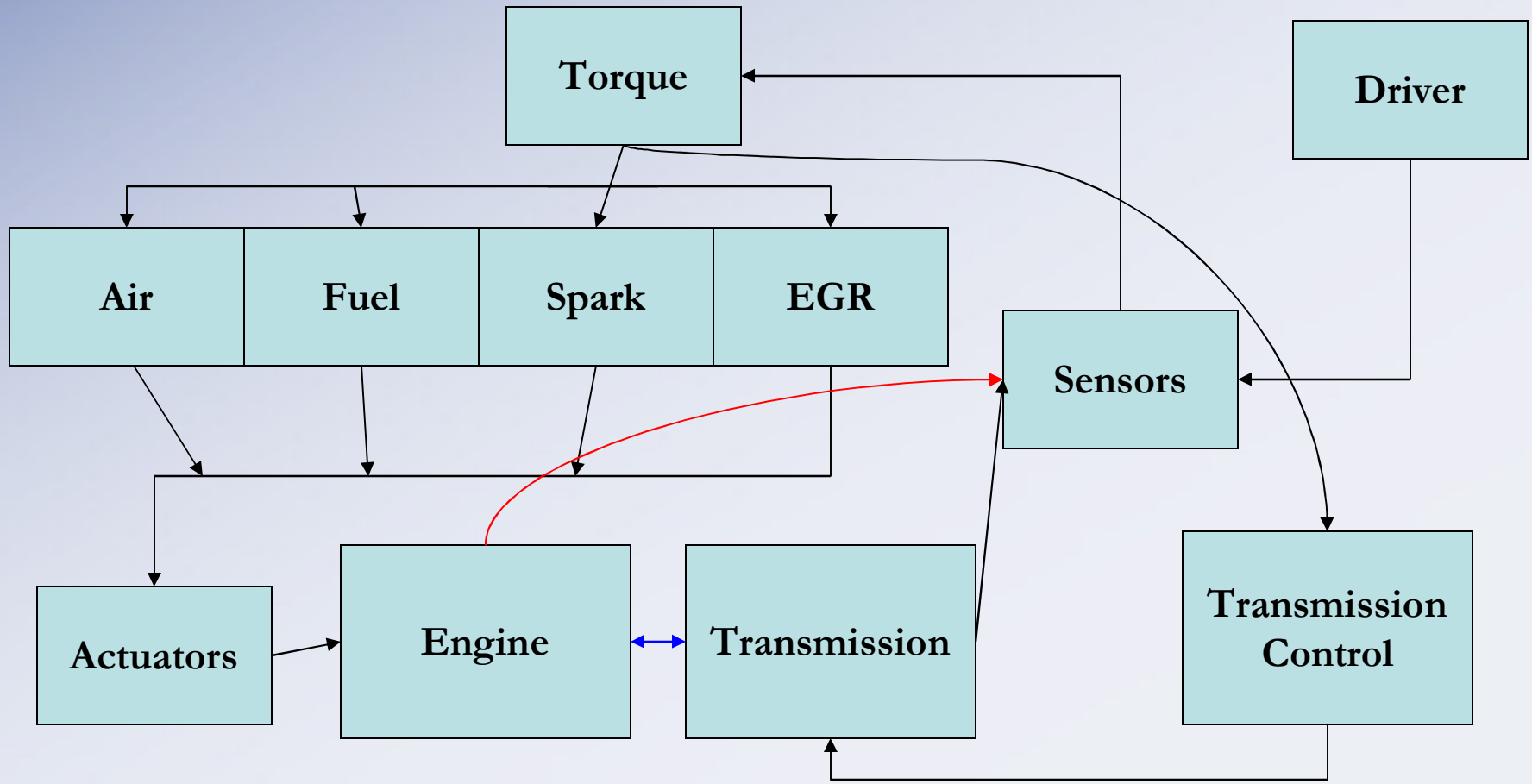
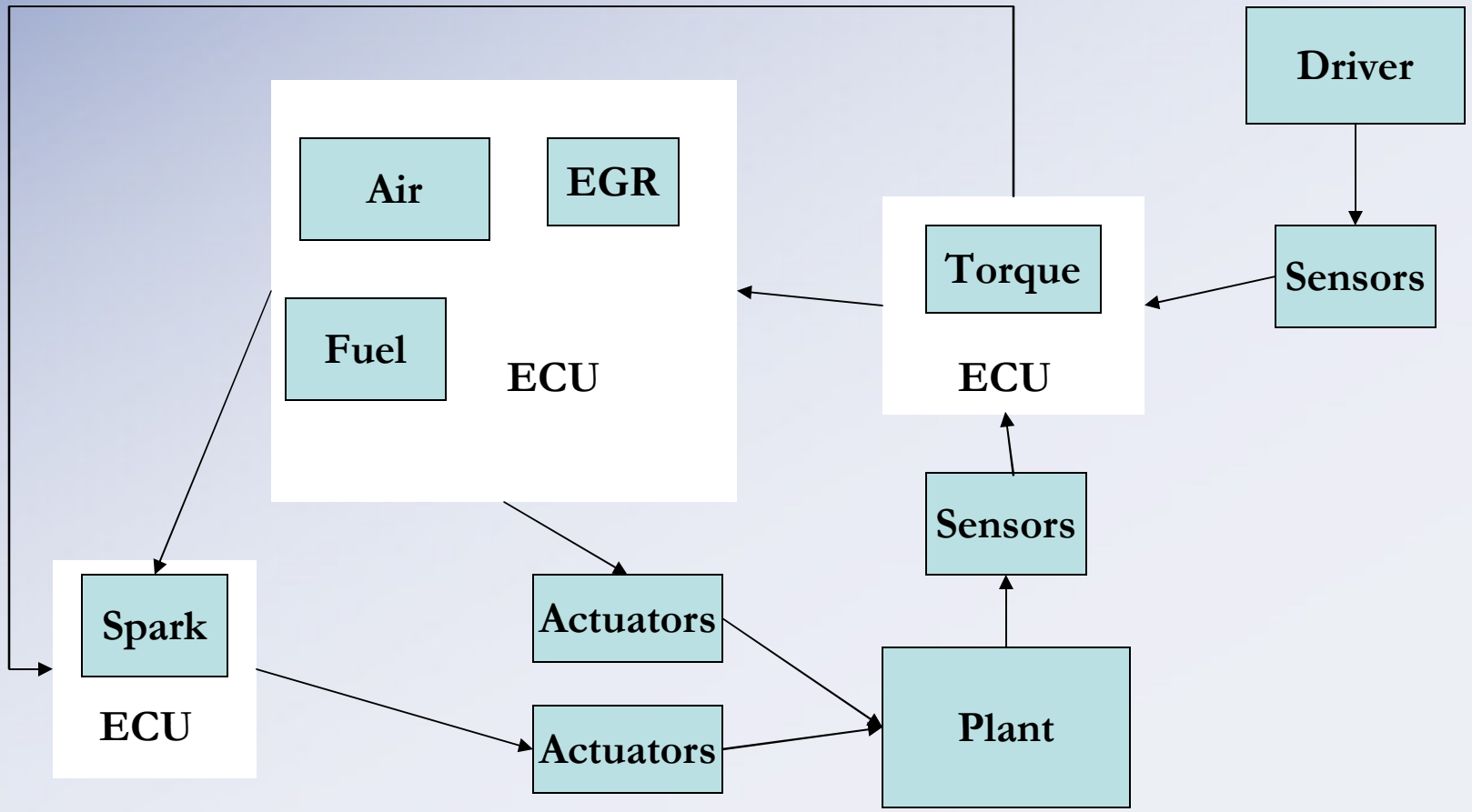
Functional Control Architecture



Deployment Architecture

- The mapping of control algorithms to processing units on the vehicle.
  - Criteria includes end to end timing, chronometric capacity of the processors, memory usage, data dependency, order of execution, rate of execution…..

Deployment Architecture



So how do we compose these views to create a coherent system view?

- To create a modern automobile you are constantly trading off between customer expectations, regulatory requirements, cost, robustness and physics.
  - The end result encompasses the physical system behavior as controlled by the embedded system.
  - This involves tradeoffs between control, software, electrical and mechanical domains.
  - Without architectural views understanding the impact of design and implementation decisions is at best difficult.

What is the next level of abstraction?

- How do we reason about systemic impacts of system design?
  - Distributed controls
  - Network communications impact
  - End to end scheduling
  - Failure modes
- It is a systems engineering function, but must be done lock step with development.
  - It cannot only be a front end process
  - Our development process, like many others, is top/down, bottom/up and sliding in from the side.

And the answer is….

- Architecure
  - The system engineering level of abstraction.
  - Able to ensure that impact of design decisions at any level can be traced to assess the overall impact of that decision.

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SMART ADAPTIVE VEHICLE

Autonomous driving - Vehicle “sees”, “learns”, and “drives” by itself